PORTABLE KILN FOR MAKING CHARCOAL FROM FORESTRY WOOD WASTE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This utility patent application claims priority from US Provisional Patent Application Serial No. 60/266,661 filed February 6, 2001, having the same title.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

[0002] The present invention relates to a portable kiln for making charcoal from forestry wood waste.

DISCUSSION OF RELATED ART

[0003] Conventionally, charcoal is made by using either an earth pit or a brick kiln. Most of the cost in the manufacture of charcoal is that which is associated with the transportation of the raw wood to the central processing site. For example, cut trees are transported by truck or train to a centralized processing site, where the charcoal is manufactured.

[0004] Approximately one third of the volume of trees cut down is not transported to the central processing site, meaning that loggers must cut down fifty percent (50%) more trees than if the entire

tree is used. Thus, more trees are cut down because the centrally located kilns do not utilize the leftover. Also, the planting of new trees is also inhibited because of the abundance of wood waste.

[0005] The leftover wood is typically discarded and left on the forest floor. While the leftover wood is still moist, new types of fungi and insect species appear on the leftover wood, which can ruin new tree generation and may adversely affect human health. In addition, once the leftover wood becomes dry it becomes extremely combustible. The presence of combustible matter throughout the forest is a significant reason for increased forest fires.

[0006] Such leftover wood turns the forest into a carbon dioxide (CO2) supplier, instead of a natural "sink" that soaks up gases responsible for the "greenhouse" effect that causes global warming, and thereby jeopardizes the balance of the existing ecosystem. On the other hand, usable wood which is not of sufficient volume to be transported cost effectively is either disposed of or salvaged by expensive and time consuming techniques. However, it never gets used in a charcoal making process.

[0007] The traditional method of making charcoal in an earth pit requires several days, or even weeks, for the wood to be properly seasoned and dried prior to being heated. Furthermore, the charcoal and by-products, which are tar and ash, can not be fully recovered because they all seep into the earth. Another disadvantage is that the recovered charcoal is often contaminated with earth and stones. Making charcoal using this method can often take more than one week after the wood is dried.

[0008] The traditional method of making charcoal in centrally located brick kilns on the other hand has no problems with loss of charcoal, because in most brick kilns tar condensation is not collected. However, brick kilns require constant supervision.

[0009] The carbonization stage may be decisive in charcoal production even though it is not the most expensive one. Unless it is carried out as efficiently as possible, it puts the whole operation of charcoal production at risk since low yields in carbonization reflect back through the whole chain of production as increased costs and waste of resources.

[0010] Wood consists of three main components: cellulose, lignin and water.

[0011] The cellulose and lignin and some other materials are tightly bound together and make up the material we call wood. The water is absorbed or held as molecules of water on the cellulose/lignin structure. Air dry or "seasoned" wood still contains 12 to 18% of absorbed water. Growing, freshly cut or "unseasoned" wood contains, in addition, liquid water to give a total water content of about -40 to 100% expressed as a percentage of the oven dry weight of the wood.

[0012] The water in the wood has to be driven off as vapor before carbonization can take place. To evaporate water requires a lot of energy so that using the sun to pre-dry the wood as much as possible before carbonization greatly improves efficiency. The water remaining in the wood to be carbonized must be evaporated in the kiln or pit and this energy must be provided by burning some of the wood itself which otherwise would be converted into useful charcoal.

[0013] The first step in carbonization in the kiln is drying out of the wood at 100°C or below to zero moisture content. The temperature of the oven dry wood is then raised to about 280°C. The energy for these steps comes from partial combustion of some of the wood charged to the kiln or pit and it is an energy absorbing or endothermic reaction.

[0014] When the wood is dry and heated to around 280°C, it begins to spontaneously break down to produce charcoal plus water vapor, methanol, acetic acid and more complex chemicals, chiefly in the form of tars and non-condensable gas consisting mainly of hydrogen, carbon monoxide and carbon dioxide. Air is admitted to the carbonizing kiln or pit to allow some wood to be burned and the nitrogen from this air will also be present in the gas. The oxygen of the air is sued up in burning part of the wood charged.

[0015] The spontaneous breakdown or carbonization of the wood above a temperature of 280°C liberates energy and hence this reaction is said to be exothermic. This process of spontaneous breakdown or carbonization continues until only the carbonized residue called charcoal remains. Unless further external heat is provided. the process stops and the temperature reaches a maximum of about 400°C. This charcoal, however, will still contain appreciable amounts of tarry residue, together with the ask of the original wood. The ask content of the charcoal is about 3 to 5%; the tarry residue may amount to about 30% by weight and the balance is fixed carbon – about 65 to 70%. Further, heating increases the fixed carbon content by driving off and decomposing more of the tars. A temperature of 500°C gives a typical fixed carbon content of about 85% and a volatile content of about 10%. The yield of charcoal at this temperature is about 33% of the weight of the oven dry

wood carbonized – not counting the wood, which was burned to carbonize the remainder. Thus the theoretical yield of charcoal varies with temperature of carbonization due to the change in its content of volatile tarry material. The following table shows the effect of final carbonization temperature on the yield and composition of the charcoal.

[0016] Effect of carbonization temperature on yield and composition of charcoal

Carbonization Temperature °C	Chemical analysis of charcoal		Charcoal yield based on oven dry wood (0% moisture)
	Of fixed charcoal	% volatile material	
300	68	31	42
500	86	13	33
700	92	7	30

[0017] Low carbonization temperatures give a higher yield of charcoal but this charcoal is low grade, is corrosive due to its content of acidic tars, and does not burn with a clean smoke-free flame. Good commercial charcoal should have a fixed carbon content of about 75% and this calls for a final carbonizing temperature of around 500°C.

[0018] The yield of charcoal also shows some variation with the kind of wood. There is evidence that the lignin content of the wood has a positive effect on charcoal yield. A high lignin content gives a high yield of charcoal. Therefore, mature wood in sound condition is preferred for charcoal production. Dense wood also tends to give a dense, strong charcoal, which is also desirable. However, very dense woods sometimes produce a friable charcoal because the wood tends to shatter during carbonization. The friability of charcoal increases as carbonization temperature

increases and the fixed carbon content increases as the volatile matter content falls. A temperature of 450 to 500°C gives an optimum balance between friability and the desire for a high fixed carbon content.

[0019] The many variables possible in carbonization make it difficult to specify an optimum procedure – generally the best results will be obtained by using sound hardwood of medium to high density. The wood should be as dry as possible and usually be split to eliminate pieces more than 20 dm thick. Firewood, which will be burned up inside the kiln or pit to dry out and start carbonization of the remainder, can be of inferior quality and temperature. One should try and reach a final temperature of around 500°C through the whole of the charge. With pits this is difficult since the air circulation and cooling effects are irregular and cold spots occur. These produce "brands" of uncarbonized wood. Trying to reach a final overall temperature of 500°C with a pit or kiln having poor and irregular air circulation usually results in burning part of the charcoal to ashes, while leaving other parts of the charge only partly carbonized. Hence the importance of using well designed kilns properly operated for an efficient charcoal operation.

[0020] Carbonization produces substances, which can prove harmful, and simple precautions should be taken to reduce risks.

[0021] The gas produced by carbonization has a high content of carbon monoxide, which is poisonous when breathed. Therefore, when working around the kiln or pit during operation and when the kiln is opened for unloading, care must be taken that proper ventilation is provided to allow

the carbon monoxide, which is also produced during unloading through spontaneous ignition of the hot charcoal, to be dispersed.

[0022] The tars and smoke produced from carbonization, although not directly poisonous, may have long-term damaging effects on the respiratory system. Housing areas should, where possible, be located so that prevailing winds carry smoke from charcoal operations away from them and batteries of kilns should not be located in close proximity to housing areas.

[0023] Wood tars and pyroligneous acid can be irritant to skin and care should be taken to avoid prolonged skin contact by providing protective clothing and adopting working procedures which minimize exposure.

[0024] The tars and pyroligneous liquors can also seriously contaminate streams and affect drinking water supplies for humans and animals. Fish may also be adversely affected. Liquid effluents and waste water from medium and large scale charcoal operations should be trapped in large settling ponds and allowed to evaporate so that this water does not pass into the local drainage system and contaminate streams.

[0025] Fortunately kilns and pits, as distinct from retorts and other sophisticated systems, do not normally produce liquid effluent – the by-products are mostly dispersed into the air as vapors. Precautions against airborne contamination of the environment are of greater importance in this case.

[0026] Charcoal ready for use by the consumer implies a certain sequence of steps in a production chain all of which are important and all of which must be carried out in the correct order. They have varying incidence on production cost. Noting these differences enables the importance of each step or unit process to be assessed so that attention may be concentrated on the most costly links of the production chain.

[0027] Charcoal is the solid residue remaining when wood is "carbonized" or "pyrolysed" under controlled conditions in a closed space such as a charcoal kiln. Control is exercised over the entry of air during the pyrolysis or carbonization process so that the wood does not merely burn away to ashes, as in a conventional fire, but decomposes chemically to form charcoal.

[0028] Air is not really required in the pyrolysis process. In fact, advanced technology methods of charcoal production do not allow any air to be admitted resulting in a higher yield, since no extra wood is burned with the air and control of quality is facilitated.

[0029] The pyrolysis process once started, continues by itself and gives off considerable heat. However, this pyrolysis or thermal decomposition of the cellulose and lignin of which the wood is composed does not start until the wood is raised to a temperature of about 300° Celsius.

[0030] In the traditional charcoal kiln or pit some of the wood loaded into the kiln is burned to dry the wood and raise the temperature of the whole of the wood charge so that pyrolysis starts and continues to completion by itself. The wood burned in this way is lost. By contrast, the success of

sophisticated continuous retorts in producing high yields of quality charcoal is due to the ingenious way in which they make use of the heat of pyrolysis, normally wasted to raise the temperature of the incoming wood so that pyrolysis is accomplished without burning additional wood. Although some heat impact is needed to make up for heat losses through the walls and other parts of the equipment. The combustible wood gas given off by the carbonizing wood can be burned to provide this heat and to dry the wood. All carbonizing systems give higher efficiency when fed with dry wood since removal of water from wood needs large inputs of heat energy.

[0031] The pyrolysis process produces charcoal which consists mainly of carbon together with a small amount of tarry residues, the ash contained in the original wood, combustible gases, tars, a number of chemicals – mainly acetic acid and methanol – and a large amount of water which is given off as vapor from the drying and pyrolitic decomposition of the wood.

[0032] When pyrolysis is completed, the charcoal that has arrived at a temperature of about 500°C is allowed to cool down without access of air. It is then safe to unload and ready for use.

[0033] The overwhelming bulk of the world's charcoal is still produced by the simple process briefly described hereunder. It wastefully burns part of the wood charge to produce initial heat and does not recover any of the by-products or the heat given off by the pyrolysis process.

[0034] Other woody materials such as nutshells and bark are sometimes used to produce charcoal. Wood is, however, the preferred and most widely available material for charcoal

production. Many agricultural residues can also produce charcoal by pyrolysis but such charcoal is produced as a fine powder, which usually must be briquetted at extra cost for most charcoal uses. In any case, encouraging the wider use of crop residues for charcoal-making or even as fuel is generally an unwise agricultural practice although the burning of sugar cane bagasse to provide heat in sugar production and the burning of cornstalks and coarse grasses as domestic fuel in some regions do provide an overall benefit where carried out as part of a national agricultural policy.

[0035] On the grounds of availability, properties of the finished charcoal, and sound ecological principles wood remains the preferred and most widely used raw material and there appears to be no reason why this should change in the future.

Charcoal making can be divided into several stages or unit operation. They are:

growing the fuel wood, wood harvesting, drying and preparing the wood for carbonization, carbonizing the wood to charcoal, screening storage and transporting to warehouse or distribution points.

[0036] It would be desirable to provide a method and apparatus for making charcoal in a mobile, potable kiln unit that can use all wood waste cost effectively. It is a further object of this invention to provide a method and apparatus for making charcoal in a mobile, portable kiln unit with minimal need for supervision. It is a further object of this invention to provide a method and apparatus for making charcoal in a mobile, portable kiln unit in all environmental settings.

SUMMARY OF THE INVENTION

[0037] One aspect of the invention resides in a mobile kiln for making charcoal from wood waste. The kiln is transported to a forested area that is being, or recently has been logged. The wood waste employed is any part of a cut tree that has not been transported, including portions of the tree trunk, large branches, small branches, bark and peat. The kiln, which in its preferred embodiment includes of three main parts – a bottom cylinder, an upper cylinder and a cover – is assembled while being loaded with the wood waste. The kiln can be placed on the ground or on a vehicle, such as a flat bed truck. Once the kiln is assembled and filled, the wood is consumed to make charcoal. During the carbonization process, the kiln can be transported. Once the carbonization process is completed, the kiln can be easily emptied of both the charcoal and byproducts.

[0038] Another aspect of the present invention is a method for preparing a portable kiln to turn wood waste into a charcoal, which is comprised of the steps of transporting the unassembled portable kiln to a site of wood waste, assembling the portable kiln by placing a base on a flat area, placing loose earth or sand around the base, placing air channels radially around the base, and filling the base with wood waste so as to avoid blocking the air channels with wood waste. A further aspect of this method may include use of a bottom section and an upper section to constitute the base, wherein the bottom section is filled with wood waste, the upper section is secured to the bottom section, and then it is also filled with wood waste. The kiln can then be lit to transform the wood into charcoal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0039] For a better understanding of the present invention, reference is made to the following description and accompanying drawings, while the scope of the invention is set forth in the appended claims.

[0040] Fig. 1 is an elevation view of the portable kiln in an unassembled condition on a trailer vehicle equipped with a crane.

[0041] Fig. 2 is an exploded view of the portable kiln of Fig. 1.

[0042] Fig. 3 is a top view of the bottom section of the portable kiln of Fig. 1, but with waste wood stacked inside.

[0043] Fig. 4 is a side view of the bottom section of Figs. 2 and 3.

[0044] Fig. 5 is a cross-section across 5-5 of Fig. 2.

[0045] Fig. 6 is a cross-section across 6-6 of Fig. 2.

[0046] Fig. 7 is a cross-section across 7-7 of Fig. 2.

[0047] Fig. 8 is a cross-section across 8-8 of Fig. 2.

[0048] Fig. 9 is a cross-section across 9-9 of Fig. 2.

[0049] Fig. 10 is a front view of handles.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0050] A portable kiln unit arrives at a forest or other logged site for processing the wood waste that remains that the site. Wood waste include anything from unused tree trunks to small branches, bark, peat and nuts. The portable kiln unit may be transported via a flat top truck or a flat bed trailer.

[0051] As can be seen in Figs. 1 and 2, the portable kiln includes a base and a lid. The base may include a plurality of sections, such as a bottom section **10** and an upper section **20**. The lid may be a unitary cover **30** or be made of a plurality of segments joined together. The bottom section **10** and the upper section **20** may be of any geometric shape, such as cylindrical. If cylindrical, the cover **30** may be conical. Otherwise, the cover **30** preferably converges upwardly as it extends from the upper section **20**. Each section is preferably made from a sheet metal. The kiln can be transported to a site atop a flatbed trailer **50** that is equipped with a crane **60** in either an unassembled condition (Fig. 1) or an assembled condition (Fig. 2).

[0052] In the unassembled condition of Fig. 1 for transport, the bottom section **10** and upper section **20** are nested together by inserting the upper section **20** into the bottom section **10**. The cover **30** is positioned inside of the upper section **20**, such that it is firmly wedged and secured

against slippage. Preferably, the nested bottom section, upper section **20** and cover **30** are arranged on a flatbed trailer **50** or flatbed truck, preferably large enough to accommodate more than one portable kiln.

[0053] The bottom section **10** has an upper inward shelf **12** (Fig. 5) and a lower outward shelf **14** (Fig. 6), both having a right angle secured to a wall of the bottom section **10**. The upper section **20** has an upper inward shelf **22** (Fig. 5) that has a right angle secured to a wall of the upper section and a reinforcement panel **24** (Fig. 7) that is straight in alignment with the wall of the upper section **20**. The reinforcement panel **24** reinforces and strengthens the lower portion of the wall of the upper section **20**.

[0054] The cover **30** has an inward shelf **32** that is right angled, but with its lower part protruding inwardly beneath a lower perimeter of the central portion of the cover **30**. The cover **30** may be equipped with handles **34** (Figs. 1, 2,10) to enable lifting with the crane **60** or enable manual movement of the cover **30**.

[0055] Preferably, the cover **30** is conical with four exhausts **40** equidistant between their neighbors. Each exhaust includes an steam release port **44** into which is fitted a steam cover **42**. The steam cover **42** is elongated with a ring projecting from its middle region. The ring rests upon a protruding edge of a hole in the cover **30** that is bounded by the steam release port **44** (see Fig. 9).

[0056] In the unassembled condition on a flatbed trailer or truck, the cover **30** is arranged with its open bottom on the flatbed and within the confines of the upper section **20**. The upper inward rim **22** of the upper section is above the conical top of the cover **30**. The upper section **20** is within the confines of the bottom section **10**, whose upper inward rim **12** is arranged above the upper inward rim **22**.

[0057] To assemble the unassembled portable kiln, the crane **60** may be used to remove each section of the portable kiln separately. The upper section **20** is to be stacked on the upper inward shelf **12** of the bottom section **10**. The inward shelf **32** of the cover **30** is to be stacked on the upper inward shelf **22** of the upper section **20**.Whether unassembled yet nested (Fig 1) or assembled (Fig. 2), the portable kiln uses the same floor space on the flatbed trailer. As should be apparent, the inside diameter of the bottom section **10** is larger than the outside diameter of upper section **20** and larger than the outside diameter of the inward shelf **32** of the cover **30**.

[0058] The kilns can be easily transported using a flat-bed truck or flat-bed trailer **50** (see Fig. 1). To transport the kiln in the back of a pick-up vehicle, the two sections **10, 20** can be nested together by inserting the upper section **10** into the lower rim of the bottom section **20** and rolled onto the back of the vehicle using a wooden ramp. The cover **30** can be positioned inside the nested sections **10, 20** and the load should be firmly wedged and tied to prevent rolling.

[0059] Care must be taken when unloading the sections **10, 20** from vehicles. If the sections **10, 20** are dropped onto their sides, then distortions are likely and difficulties will be encountered when

attempts are made to assemble the sections **10, 20** during use. Slight distortion can be tolerated but severe distortion should be corrected using a car jack and two lengths of timber inserted across the diameter of the damaged section.

[0060] Fig. 2 also shows a plurality of air channels **80**, each with a supporting collar **82** onto which may be fitted a smokestack **90**. Each air channel **80** includes a horizontal portion that is hollow with opposite ends that are open and an opening between the opposite ends that is in communication with the interior hollow space defined by the supporting collar **82**.

[0061] For economy of labor, two or more kilns may be operated as a group within reasonable walking distance of each other. This enables operators to unload and load one unit when the other kilns are in the carbonization or cooling stage.

[0062] To avoid the unnecessary carrying of wood, the kilns should frequently be rolled to new sites adjacent to the wood supply. The individual sections of the kiln can be rolled by two or three men, usually with two men pushing from behind and one main guiding the section from the front. Wooden levers are recommended for tipping the individual sections onto their sides prior to rolling them to a new position. Rolling the sections is far easier than sliding them horizontally, even where distances of only 1 or 2 meters are concerned. The task of manipulating these kilns on the forest floor becomes considerably easier with experience.

[0063] Choosing a flat area on the forest floor is recommended. A well-drained and roughly leveled area, approximately 3 meters in diameter, should be chosen, in close proximity to the wood supply. Tree stumps and large root systems should be avoided and excessive undergrowth should be removed from the chosen area and the ground made firm by stamping it down. Loose earth or sand should be available close to the site for sealing off the air supply to the kiln during operation. A sandy or loamy soil is preferred and, if not available, a supply of sand should be obtained from a nearby stream for the initial operations. This material can be re-used and will soon increase in volume as charcoal dust and wood ash, produced during successive operations, are incorporated into it.

[0064] The wood should be felled, cut up and stacked at least three weeks before kilning, if the maximum yield of charcoal is to be obtained. Dry wood needs less charring time and increases the conversion efficiency of the process. The size of wood most suitable is between 450 to 600 mm long and up to 200 mm in diameter. Branches up to 900 mm long can be included provided their diameters preferably do not exceed 130 mm and the packing density in the kiln is not markedly reduced. Logs with diameters approaching 300 mm may be used provided they are cut into lengths no greater than 300 mm. Wood with a diameter greater than 300 mm should be split before use.

[0065] Branches with a diameter of less than 40 m should not be mixed in the same charge with timber of maximum diameter. This material should be charged with other small to medium size wood. Approximately 7 stacked cubic meters of wood are required to fill the kiln.

[0066] Tools required for a 2 or 3 man operation of the kiln:

Chainsaw or crosscut saw	Wooden pole or plank
2 shovels or spades	Sieve chute
Cutlass	Sacks
Axe Sledge hammer	Needles and string
2 Wedges	Heat proof gloves

[0067] The assembly and loading of the kiln is completed as follows. The bottom section 10 of the kiln is rolled onto the prepared site and lowered into its operating position. Using a wooden pole as a lever the eight-air inlet channels are inserted open side down radially underneath the bottom section at equidistant intervals. Equal spacing will be easily achieved f the first four channels are inserted at 90° intervals and the remaining four inserted between them.

[0068] Each air channel 80 should protrude a minimum of 250 mm into the kiln to prevent overheating of the kiln wall. The supporting collar 82 on the top of the channel should not lean inwards towards the kiln wall, otherwise it will be difficult to position the chimneys once the kiln has been assembled. When the inlet-outlet air channels 80 are in position, it is necessary to check that they are completely clear of any obstruction.

[0069] The bottom of the kiln is loaded with wood making sure that the ends of the inlet/outlet air channels 80 and the spaces between them are not blocked. To achieve this, the charge is

supported on "stringers" which are medium diameter (150 mm) pieces of cordwood arranged radially like the spokes of a wheel.

[0070] At each quadrant of the kiln`s base dry kindling wood, together with any inflammable waste (paper, sump oil, etc.) is placed between the stringers from the edge of the bottom of the kiln to the center to provide four lighting points.

[0071] A bridge of small/medium diameter wood and branch (incompletely charred wood from a previous firing) is now placed across the stringers over the kindling in the shape of a cross. Bridging the remaining exposed stringers with small/medium diameter wood completes the base layer of the kiln.

[0072] By supporting the first layer of wood above the ground on stringers, air ducts are formed under the charge, which will allow the dire to spread more rapidly into the center of the kiln.

[0073] The bottom section **10** of the kiln is loaded with successive layers of wood **70**, filling in the vacant space as much as possible and placing the larger diameter timber towards the center of the kiln. When the bottom section 10 is full and all the joint surfaces of the kiln are scraped clean, the upper section **20** is rolled alongside. The upper section **20** is then pushed up on to the supporting shelf **12** of the bottom section **10**.

[0074] The loading of wood **70** is continued until the charge forms a conical shape above the rim of the upper section **20** but, at the same time, will allow the cover **30** to be located into the rim without hindrance. The cover **30** is then rolled alongside the kiln and pushed up onto its supporting shelf **22**. Two experienced men can load the kiln in about two hours.

[0075] After ensuring that all four steam release ports **44** in the cover **30** are open, a flame is applied to the four lighting points. Where there is a prevailing wind, the area of the kiln on the windward side will burn more quickly. To allow for this, the lighting points facing the wind are not lit until the lee side of the kiln is well alight.

[0076] The kiln is allowed to burn freely for about 30 minutes until the bottom section at each lighting point becomes so hot that it is unpleasant to stand close to the kiln. During this period, copious amounts of steam will be released from the four steam release ports **44** in the cover **30** of the kiln. While this is in progress the joints between the bottom and upper sections **10, 20** of the kiln are filled with sand or soil and the four smoke stacks are placed into position over the supporting collars **82** of each alternate air channel **80**.

[0077] As each sector of the kiln reaches the required temperature, the spaces between the inlet/outlet air channels **80** are covered with sand or soil. When all the spaces between the channels have been covered, the open ends of the four channels supporting the smokestacks **90** are sealed. The steam release ports are now closed so that the smoke is drawn out of the base of the kiln by the four smokestacks **90**. When the drought has been reduced, air enters the kiln only through the inlet

channels from where it flows up through the center of the charge. The combustion gases are drawn down the outer edge of the kiln and are released through the smokestacks **90**. As the air and exhaust gases flow in opposite directions, this condition is known as the reverse drought.

[0078] Each smokestack **90** should emit a column of thick white smoke 15-30 minutes after promoting the reverse drought. Throughout the period of carbonization it is advisable to ensure that even temperatures are maintained around the circumference of the kiln. Control is easier when the kilns are operated in sheltered positions. If there is a strong prevailing wind, the temperature profile across the kiln may become unbalanced and it will then be necessary to partially or completely block one or two of the air inlets on the windward side. When operating in wet conditions, or with freshly felled wet wood in windy conditions, more extreme efforts may be necessary to balance the kiln during the initial stages of carbonization. Under these conditions large quantities of water will evaporate from the soil and wood on the hottest side and condense in the cooler regions of the kiln. This water is likely to quench any fires remaining in the lighting points and will further depress the temperature in these areas.

[0079] To correct this situation the air inlets on the hot side of the kiln should be temporarily blocked and the spaces between the inlet/outlet channels on the cooler side uncovered to allow more air to enter this region of the kiln. This action will draw the fire over to the cooler side of the kiln and, once the temperature in this area has been sufficiently increased, the spaces between the channels may be resealed. After this, the normal method of controlling the supply of air to the kiln can be followed.

[0080] The burning kiln should never be left unattended when the spaces between the inlets/outlets channels needs to be unsealed for whatever reason above described. Serious damages to the kiln could result from such behavior.

[0081] When wet wood is used or when the kiln is operated under wet conditions, the charring period is likely to be extended up to a total of 48 hours. Because of the increased amount of wood burned internally to drive off the excess moisture, lower yields of charcoal are to be expected.

[0082] During charring, a certain amount of tar is deposited in the outlet channels and smokestacks **90**. This tar restricts the exhaust gas flow from the kiln and should be removed when there is a noticeable reduction in the quantity of smoke issuing from any of the stacks. To achieve this, the stack is lifted off the supporting collar of the outlet channel using a pair of heat proof gloves or an old sack and any obstruction inside the smokestack **90** is removed. At the same time a long stick should be inserted through the channel into the center of the kiln to ensure that there is no internal restriction.

[0083] Some time during the carbonization period (usually 8-10 hours after lighting), the smoke stacks **90** should be moved onto the adjacent air channels to convert air inlets to smoke outlets and vice versa. This creates a more even burn and reduces the formation of ash at the regions where air enters the kiln.

[0084] Charring is complete when the color of the smoke from all smokestacks **90** takes on a bluish tinge and becomes almost transparent. This normally occurs about 16 to 24 hours after lighting. At this stage the whole surface of the kiln should be very hot (150 - 200°C) so that a spot of water applied to the wall of the kiln will evaporate immediately with a spitting noise. When this stage is reached the kiln is completely sealed for cooling.

[0085] Removing the smokestacks **90** and completely blocking all air channels **80** with soil or sand seals the kiln. If necessary, additional soil or sand is added to the joints of the sections **10**, **20** and cover **30** of the kiln and the steam release ports **44** to ensure that they are fully sealed and that no air may enter. The kiln is allowed to cool for between 16 and 34 hours before opening and unloading. Cooling will be greatly assisted if rain falls.

[0086] Unloading the kiln is effected as follows. The kiln must not be opened until the contents are cold and the outside surface of the kiln is cool to the touch. The action of direct sunlight could obscure this and the temperature of the inside of the kiln can be more easily assessed by feeling the surface of the bottom section in an area shaded from the sun. Following this the temperature of the remaining surface of the lower section should be assessed to ensure that no "hot-spots" exist. If the contents of the kiln are still hot after a cooling period of 24 hours, in this case it looks like the complete sealing from the outside air has not been effected and an effort must be made to achieve this. Furthermore, if the kiln is opened and part of the charcoal is seen to be still alight, the kiln must be resealed for a further cooling period.

[0087] During carbonization the wood will have been reduced to about half its original volume and it will be possible to remove the cover and top section once the kiln has cooled, leaving the charcoal in the lower section.

[0088] The cover **30** is removed with a minimum effort by lifting one side from its supporting shelf **22** and inserting the end of a long branch or plank into the resulting gap. This piece of wood can then be used as a ramp on which the cover is slid gently to the ground. The same method is used to remove the top section of the kiln.

[0089] To remove the bottom section **10**, the inlet/outlet air channels **80** are first removed from one side of the kiln using a lever. By applying the lever to the opposite side, the bottom section **10** can be tipped onto its side, leaving the charcoal free to be loaded into sacks. A bucket of water or a quantity of sand or soil should be on hand while unloading the kiln in order to quench any small fires.

[0090] To speed up the bagging of charcoal, a sieve chute should be used to separate the large charcoal pieces from the fines and dust.

[0091] The bottom section **10** may be positioned on the leeward side of the charcoal and used to support the sieve chute. This will not only increase the stability of the sieve but will reduce the amount of dust reaching the operator.

[0092] If required, a free standing sieve chute can also be used. Two men can unload it and fill the sacks with charcoal in about an hour.

[0093] As an alternative method of operation, lighting the kiln from the top is a method, which is particularly suitable for the carbonization of small wood or coconut shells, as it ensures a sufficient gas flow through the charge.

[0094] The kiln is loaded as previously described, without kindling between the stringers at the base. The kindling wood is placed instead in a depression 250 mm deep on top of the charge, which is then covered with a final layer of wood.

[0095] When carbonizing coconut shells, the use of stringers is not required. Care must be taken to ensure that the shell material does not block the ends of the inlet/outlet channels inside the kiln. To achieve this, a flat piece of wood (for example, a piece of rib from a dead palm frond) is placed on top of the end of each channel before covering it with shells.

[0096] The fire is lit at the top through one of the four-steam release ports and the charge is allowed to burn with a completely free access of air into the base of the kiln. The smoke will escape through the four ports in the cover. This stage is allowed to continue for about two hours until the whole of the top section of the kiln is too hot to touch with bare hands.

[0097] When the upper section **20** is sufficiently hot, the spaces between the inlet/outlet air channels **80** are covered with sand or soil and the smokestacks **90** are placed in position. The steam release ports **44** are sealed, such as with steam covers **42**. The reverse drought and control of the supply of air to the kiln are achieved as in the normal method of operation described previously.

[0098] A suggested 5-day week work plan is outlined below. Modifications can be made to this schedule to allow for variations in daily working hours and a 6-day working week. Moreover, if arrangements can be made for someone living near to the production area to undertake a half-hour period of light duty to seal the kiln during the weekend, then extra operations can be achieved.

[0099]

Monday	08.00-10.00 Kiln 1	and Kiln 2	Unload both kilns.
	10.00-12.00 Kiln 1		Load kiln with wood.
	12.00-13.00 Kiln 1		Light kiln and reduce drought
	13.00-17.00 Kiln 1		Control charring. Change and clean stacks at 16.30.
		Kiln 2	Load kiln with wood.
Tuesday	08.00-08.30 Kiln 1		Change and clean stacks
	08.30-11.00		Prepare wood for future operations
	11.00-12.00	Kiln 2	Light kiln and reduce drought

		Kiln 2	Control charring. Change and clean stacks at 16.30.
		Kiln 1	Shut down kiln when charring is complete
			Prepare wood for future operations
Wednesday	08.00-08.30	Kiln 2	Change and clean stacks
	08.30-14.00		Prepare wood for future operations
	14.00-15.00	Kiln 1	Unload charcoal from kiln
	15.00-17.00	Kiln 1	Start loading kiln with wood
		Kiln 2	Shut down kiln when charring is complete
Thursday	08.00-10.00	Kiln 1	Finish loading kiln with wood
	10.00-11.00	Kiln 1	Light kiln and reduce drought
	11.00-13.00	Kiln 2	Unload charcoal from kiln
		Kiln 1	Control charring
	13.00-15.00	Kiln 2	Load kiln with wood
		Kiln 1	Control charring
	15.00-16.00	Kiln 2	Light kiln and reduce drought
	16.00-17.00	Kiln 1	Change and clean stacks
		Kiln 2	Control charring

Friday	08.00-09.00 Kiln 1 and	Kiln 2	Change and clean stacks
	09.00-13.00 Kiln 1		Shut down kiln when charring is complete
			Prepare wood for future operations
		Kiln 2	Change and clean stacks at 12.30
	13.00-17.00		Prepare wood for future operations
		Kiln 2	Close down kiln when charring is complete.

[0100] The following seven precautions should be taken to avoid problems with operation of the kiln.

[0101] -- Make sure to insert the inlet/outlet channels sufficiently under the lower rim of the bottom section of the kiln during assembly. The high temperature produced at the inner end of the air channel causes serious damage to the kiln wall if the required distance between the hot zone and the kiln wall is not maintained.

[0102] -- Make sure to achieve sufficient gas flow through the system by not removing deposits of tar from the outlet air channels **80** and smokestacks **90**. This results in low kiln temperatures and prolonged charring periods.

[0103] -- Avoid excessive periods that are allowed for cooling the kiln, which reduce the number of operations possible in the working week.

[0104] -- Avoid being reluctant to move the kiln closer to the available wood supply, because the failure to do so results in a waste of time and effort in carrying the wood to the kiln.

[0105] -- Make sure that is a sufficient supply of wood available in the area adjacent to the kiln for loading immediately when the previous operation has been completed.

[0106] -- Avoid the practice of allowing large fires to develop next to the surface of the wall of the kiln during the lighting stage. This usually restricts the flow of air under the kiln and prevents the fire spreading quickly to the center of the charge. It can also cause serious damage to the kiln wall. Once the prepared kindling has been ignited inside the kiln, a maximum flow of air is all that is normally required.

[0107] -- Avoid the laborious and time-consuming practice of hand picking the charcoal into sacks instead of using shovels and a sieve. Excessive time spent on unloading the kiln causes a delay in loading and lighting the next operation.

[0108] The weight of charcoal produced in each batch operation of a transportable metal kiln is related to several physical factors. The main factors which contribute towards maximum yields are:

–high timber density

–low moisture content of wood

–dry operating conditions and a dry well-drained site for the kiln

–high packing density of charge obtained with regular size and shape of raw material

[0109] In practice, it is seldom that all of these conditions can be arranged and consequently the yields and conversion efficiencies might vary to a considerable degree.

[1110] The quality of charcoal is defined by various properties and through all are interrelated to a certain extent, they are measured and appraised separately. These various quality factors are discussed as follows.

[0111] Moisture Content. Charcoal fresh from an opened kiln contains very little moisture, usually less than 1%. Absorption of moisture from the humidity of the air itself is rapid and there is, with time, a gain of moisture, which even without any rain wetting can bring the moisture content to about 5 to 10%, even in well-burned charcoal. When the charcoal is not properly burned or where pyroligneous acids and soluble tars have been washed back onto the charcoal by rain, as can happen in pit and mound burning, the hygroscopitity of the charcoal can rise to 15% or even more.

[0112] Moisture is an adulterant, which lowers the calorific or heating value of the charcoal. Where charcoal is sold by weight, keeping the moisture content high by wetting with water is often done by dishonest dealers. The volume and appearance of charcoal is hardly changed by addition of water. For this reason bulk buyers of charcoal prefer to buy either by gross volume, e.g. in cubit

meters, or to buy by weight and determine by laboratory test the moisture content and adjust the price to compensate. In small markets sale is often by the piece.

[0113] It is virtually impossible to prevent some accidental rain wetting of charcoal during transport to the market but good practice is to store charcoal under cover even if it has been bought on a volume basis, since the water it contains must be evaporated on burning and represents a direct loss of heating power. This occurs because the evaporated water passes off into the flue and is rarely condensed to give up the heat it contains on the object being heated in the stove.

[0114] Quality specifications for charcoal usually limit the moisture content to around 5-15% of the gross weight of the charcoal. Moisture content is determined by oven drying a weighed sample fo the charcoal. It is expressed as a percentage of the initial wet weight.

[0115] There is evidence that charcoal with a high moisture content (10% or more) tends to shatter and produce fines when heated in the blast furnace, making it undesirable in the production of pig iron.

[0116] Volatile matter other than water. The volatile matter other than water in charcoal comprises all those liquid and tarry residues not fully driven off in the process of carbonization. If the carbonization s prolonged and at a high temperature, then the content of volatile is low. When the carbonization temperature is low and time in the kiln is short, then the volatile matter content increases.

[0117] These effects are reflected in the yield of charcoal produced from a given weight of wood. At low temperature (300°C) a charcoal yield of nearly 50% is possible. At carbonization temperatures of 500-600°C volatile are lower and retort yields of 30% are typical. At very high temperatures (around 1000°C) the volatile content is almost zeroed and yields fall to near 25%. As stated earlier, charcoal can reabsorb tars and pyroligneous acids from rain-wash in pit burning and similar processes. Thus the charcoal might be well burned but have a high volatile matter content due to this factor. This causes an additional variation in pit burned charcoal in wet climates. The reabsorbed acids make the charcoal corrosive and lead to rotting of jute bags – a problem during transport. Also it does not burn cleanly.

[0118] The volatile matter in charcoal can vary from a high of 40% or more down to 5% or less. It is measured by heating away from air, a weighed sample of dry charcoal at 900°C to constant weight. The weight loss is the volatile matter. Volatile matter is usually specified free of the moisture content, i.e. volatile matter - moisture or (V.M. - moisture).

[0119] High volatile charcoal is easy to ignite but may burn with a smoke flame. Low volatile charcoal is difficult to light and burns very cleanly. A good commercial charcoal can have a net volatile matter content - (moisture free) of about 30%. High volatile matter charcoal is less friable than ordinary hard burned low volatile charcoal and so produces fewer fines during transport and handling. It is also more hygroscopic and thus has a higher natural moisture content.

[0120] Fixed Carbon Content. The fixed carbon content of charcoal ranges from a low of about 50% to a high or around 95%. Thus charcoal consists mainly of carbon. The carbon content is usually estimated as a "difference"; that is to say, all the other constituents are deducted from 100 as percentages and the remainder is assumed to be the % of "pure" or "fixed" carbon. The fixed carbon content is the most important constituent in metallurgy since it is the fixed carbon which is responsible for reducing the iron oxides of the iron ore to produce metal. But the industrial user must strike a balance between the friable nature of high fixed carbon charcoal and the greater strength of charcoal with a lower fixed carbon and higher volatile matter content to obtain optimum blast furnace operation.

[0121] Ash Content. Ash is determined by heating a weighed sample to red heat with access of air to burn away all combustible matter. This residue is the ash. It is mineral matter, such as clay, silica and calcium and magnesium oxides, etc. present in the original wood and picked up as contamination from the earth during processing.

[0122] The ash content of charcoal varies from about 0.5% to more than 5% depending on the species of wood, the amount of bark included with the wood in the kiln and the amount of earth and sand contamination. Good quality lump charcoal typically has ash content of about 3%. Fine charcoal may have a very high ash content but if material less than 4 mm is screened out the plus 4 m residue may have an ash content of about 5 to 10%. Buyers naturally suspect fine charcoal and it is difficult to sell (and use, unfortunately).

[0123] Typical charcoal analysis found in our production in Africa.

Wood Species	Moisture content %	Ash %	Volatile matter %	Fixed Carbon %	Gross Calorific value KJ/kg
Oak	3.5	2.1	13.3	81.1	32,500
Coconut Shell	4,0	1.5	13.5	83.0	30,140

[0124] In an area of vast logging, there may be sufficient wood waste for the running of several cycles or one or more transportable kilns. Upon arriving at a logging site that will require more than one kiln cycle, the kiln should be placed in a flat area with at least the same diameter as the bottom section. In a preferred embodiment, the diameter of the bottom section **10** is three (3) meters. Loose earth or sand should be placed at the bottom of the kiln. The bottom section **10** and upper section **20** can be shifted to their side and then rolled to the desired area. In areas which do not require more than one kiln cycle, or, for the last kiln cycle in an area requiring multiple kiln cycles, the kiln can be assembled on the flatbed trailer, allowing the kiln to continue its cycle as it is transported to the next available site.

[0125] Once the bottom section **10** is placed in the desired location, air channels **80** (Fig. 3) are placed beneath and radially around the bottom section **10** (Fig. 4). The air channels **80** should be placed at equidistant intervals and protrude into the bottom section **10** to prevent overheating of the portable kiln's walls. In the preferred embodiment, the air channels **80** protrude into the bottom section **10** to a distance that is about .028 of the diameter of the bottom section **10**.

[0126] After the air channels **80** are arranged, the bottom section **10** is then loaded with the available wood waste. The length of the individual pieces of wood waste, for instance branches, is limited by the diameter of the bottom section **10**. For optimal charcoal creation, the diameter of the pieces of wood waste should not be greater than one third of the diameter of the bottom section **10**. The loading of the wood waste into the bottom section **10** should be done in such a way that the air channels **80** are not blocked. This is accomplished by placing larger pieces of wood waste, called "stringers," which typically include branches or portions of a trunk with a diameter which is of a similar size to the protrusion of the air channels **80**, radially throughout the base of the bottom section **10**. The air channels **80** have supporting collars **82** that extend vertically outside the bottom section **10**.

[0127] Thereafter, at each quadrant of the bottom section **10**, in between the stringers, dry kindling wood, together with inflammable waste, is placed between the stringers. These areas of dry kindling wood provide the lighting points. Once the lighting points are established, small or medium diameter wood waste is then placed across the stringers in the shape of a cross. Once the cross is laid down, small or medium diameter wood waste should be used to bridge the remaining exposed stringers. This method of creating a first layer of wood on stringers forms air ducts underneath the bottom layer of wood, thereby allowing the fire to spread more rapidly into the center of the kiln.

[0128] The bottom section **10** is then filled with wood waste **70**. To obtain optimal results, the larger diameter wood waste **70** is placed towards the center. Once the bottom section **10** is filled with wood waste, the base of the upper section **20** is placed on top of the upper inward shelf **12**.

The outside diameter of the upper section **20** is smaller than the inside diameter of the bottom section **10**. Because the upper inward shelf **12** is below the upper edge of the bottom section **10**, the base of the upper section **20** is held within the bottom section **10**.

[0129] Once the upper section **20** is supported by the bottom section **10**, the upper section is filled with wood waste. The wood waste **70** is loaded into the upper section **20**, such that the top of the load is conical in shape, whereby the outer edges of the load are below the upper inward rim **22** of the upper section **20**, and the top of the load rises above the top of the upper section **20**.

[0130] Once the upper section **20** is completely loaded, the cover **30** is placed on top of the upper section **20**. The outside diameter of the cover **30** is slightly smaller than the inside diameter of the upper section **20**. Because the upper inward rim **22** is below the upper edge of the upper section **20**, the lower portion of the cover **30** is held within the upper section **20**. The cover **30** (Fig. 6) also contains four steam release ports **44**. The steam release ports **44** are left open during the combustion and charring process, but closed after the charring process is complete.

[0131] Seams between the upper and lower sections, between the upper section and the cover, and between the lower section and the base should be sealed to prevent air flow. This sealing may be effected in a cost effective manner by covering the seams with sand of dirt or other sealing material, such as a heat resistant paste or compound.

[0132] When the portable kiln is loaded and assembled, the steam release ports **44** are open and all the air channels **80** are open. A flame is then applied to the four lighting points of the dry, smaller size kindling wood within the periphery of the kiln towards the bottom. The kiln is then allowed to burn freely. After 5-10 minutes, smokestacks **90** are erected at every other one of the air channels **80**, by securing a vertically directed tubular smokestack **90** onto a supporting collar **82** that is outside of the kiln. Each smokestack **90** may be of a height that reaches an elevation higher than the apex of the cover **30** and is approximately the same diameter as that of the diameter of the supporting collar **82**.

[0133] In the event that seams between the upper and lower sections **10, 20** and between the upper section **20** and the cover **30** are not sealed, smoke may emerge through them. Any such smoke emerging through the seams signifies the need to add more sand or dirt or other sealing paste or compound to the seals at locations where the smoke emerges until the smoke no longer emerges through the seams.

[0134] Once the kiln reaches a temperature of approximately 100 degrees centigrade and kept at that temperature for thirty (30) minutes, the steam release ports **40** are closed and the kiln remains at 150 to 200 degrees centigrade for approximately 12 - 16 hours, while the wood waste chars. Charring is complete when the smoke coming out through the inlets takes on a bluish tinge. At that time, all of the air channels are sealed, and the kiln is allowed to cool for approximately 8 - 10 hours depending upon the atmospheric temperature outside, before it is opened and unloaded. The kiln is opened when the kiln is cool to the touch.

[0135] Although the preferred embodiment employs four steam release ports **44** in the cover **30**, the present invention envisions the use of any number of ports, even if only one is used. Further, although the preferred embodiment employs eight air channels **80** and four smokestacks **90**, any number of air channels and smokestacks may be used. For instance, the four inlet air channels **80** may be joined together to share a common air intake header. Also, the four smokestacks may be joined to share a common exhaust chimney. Furthermore, various sensors and detectors may be arranged to detect various conditions of the kiln, such as its temperature and the emission of bluish smoke. Where appropriate the detectors may make an indication to observers and/or send signals to drivers that will perform the tasks which this application mentioned may be done manually, such as opening or sealing off certain open ports and intakes.

[0136] While the foregoing description and drawings represent the preferred embodiments of the present invention, it will be understood that various changes and modifications may be made without departing from the spirit and scope of the present invention.